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[Title of the Invention] CONTROL CIRCUIT FOR LIGHT-EMITTING DIODE

[Claims for the Patent]

[Claim 1] A control circuit for a light-emitting diode characterized by comprising:

control LED determination means for determining a light-emitting diode to be controlled;

operating point judgment means for judging an operating point to shift from a lit-on state to a lit-off state or vice versa for the light-emitting diode selected by the control LED determination means;

lighting-up time period determination means for determining the time period to light up the light-emitting diode based on the operating point judged by the operating point judgment means; and

lighting-up control means for driving the light-emitting diode based on the output of the lighting-up time period determination means.

[Detailed Description of the Invention]

[Field of the Invention]

The present invention relates to a control circuit for gradually changing the luminance of a light-emitting diode in lighting up or off.

[Conventional Art]

As such a type of control circuit, a conventional circuit shown in Fig. 1 has been proposed. That is, in said figure, 1 is an oscillation circuit, 2 is a counter circuit connected to the oscillation circuit 1, 3 is a decoder circuit connected to the counter circuit 2, 4 is a current-drive circuit connected to each output of the decoder circuit 3, 5 is a first input resistor connected between the output of the decoder circuit 3 and the base of a first transistor 6, 7 is a first light-emitting diode

(hereinafter referred to as LED) controlled by the output of the first transistor 6, 8 is a first current-limiting resistor connected in series with the first LED 7, 9 is a second input resistor connected in series between another output of the decoder circuit 3 and the base of a second transistor 10, 11 is a second LED controlled by the output of the second transistor 10, 12 is a second current-limiting resistor connected in series with the second LED 11, 13 is a third input resistor connected in series between another output of the decoder circuit 3 and the base of a third transistor 14, and 15 is a third current-limiting resistor controlled by the output of the third transistor 14.

Next, the operation of the control circuit will be described referring to Fig. 2. In Fig. 2, diagrams a, b and c show the luminance change of each of the first LED 7, the second LED 11, and the third LED 15 described above. In Fig. 1, first, the counter circuit 2 performs counting in synchronous with an oscillation output outputted from the oscillation circuit 1. The output of the counter circuit 2 is inputted to the decoder circuit 3. At this point, the decoder circuit 3 outputs a "H" level signal only for one output at a certain time according to the output pattern of the counter circuit 2. Thereby, a corresponding transistor is turned on and a current is passed to light up the LED on the load side thereof. Thus, the lighting condition of the first LED 7, the second LED 11, and the third LED 15 change as shown in Fig. 2.

However, the above described conventional control circuit of light-emitting diodes had a disadvantage in that when each LED 7, 11, 15 is shifted from a lit-on state to lit-off state or vice versa, its luminance abruptly changes, and therefore a gradual luminance change of the LED not being perceived.

[Summary of the Invention]

Therefore, the present invention has been contemplated to overcome the above described disadvantage of the conventional art, and its object is to provide a control circuit for a light-emitting diode whereby the LED is adapted to shift from

a lit-on state to a lit-off state or vice versa with a gradual luminance change by pulse-driving the LED to successively change its lighting duty in the lighting-up or lighting-off operation.

[Embodiments of the Invention]

Figure 3 is a general block diagram to show an embodiment of the control circuit for a light-emitting diode according to the present invention. In the figure, the control circuit for a light-emitting diode comprises: control LED determination means 21 for determining which LED is to be controlled; operating point judgment means 22 for judging in what time point of the lighting-up or lighting-off operation is the LED to be controlled based on the output of the control LED determination means 21; lighting-up time period determination means 23 for determining the time period to light up the LED according to the output of the operating point judgment means 22; and lighting-up control means 24 for driving the LED based on the output of the lighting-up time period determination means 23, and is configured to perform the lighting-up and lighting-off control of the LED 25.

Fig. 4 is a circuit diagram to show the electric connections of Fig. 3, in which the identical numbers are given to the identical parts as those in Figure 1 and the description thereof is omitted. In the figure, 30 denotes a microcomputer and this microcomputer 30 consists of a CPU 31, a memory 32, an input circuit 33, an output circuit 34, and a timer circuit 35. Further, 36 is a switching device connected to the input circuit 33, 37 is a resistor connected in series between the input circuit 33 and the switching device 36, and a power source. Furthermore, each input resistor 5, 9 and 13 of the current-drive circuit 4 is connected to the microcomputer output circuit 34, respectively.

Next, the operation of the control circuit will be described referring to Figures 5 to 7. Fig. 5 is a flowchart to show a control program stored in the memory 32 of the microcomputer 3; and Figures 6a and 6b are diagrams to illustrate the control operation of the lighting-up time of the LED, Fig. 6a showing the drive current of the LED and Fig. 6b showing the luminance thereof; Figs. 7a, 7b and 7c are schematic diagrams

to illustrate the luminance changes in the lit-up and lit-off states of each LED 7, 11, 15. In Fig. 4, first, when the switching device 36 is turned on (step 50 in Fig. 5), its on-signal is inputted to the input circuit 33 to select a LED to be lit up (step 51 in Fig. 5). In this case, for this selection operation, methods such as reading out patterns pre-stored in the memory 32 and generating pseudo-random numbers by programming can be used. Next, considering the case in which the LED is shifted from a lit-up state to a lit-off state, a lighting-up time ratio $t_1 : t_2$, wherein, for example, lighting-up time $t_1 = 1$ and lighting-off time $t_2 = 15$, is set (step 52 in Fig. 5), and then the LED selected in the step 51 is lit on (step 53 in Fig. 5) and after an lapse of time t_1 (step 54 in Fig. 5), the LED is lit off (step 55 in Fig.5). Then, after a lapse of time t_1 (step 56 in Fig. 5), the above described lighting-up and lighting-off operations are repeated by a specified number of times (step 57 in Fig. 5), and thereafter the lighting-up time ratio is set such that $t_1'=2$ and $t_2'=14$ (step 58 in Fig. 5), and the operations of steps 53 to 57 are repeated. In this operation, the period of lighting-up and lighting-off t_0 $(=t_1 + t_2)$ is set to be not more than 1/100 sec so that any luminance flicker will not be perceived. By these operations, the LED is shifted to a lit-up state in a step-wise manner with the luminance increasing as shown by (1), (2), (3),.. in Fig. 6b. And, the number of these steps is set to be no less than eight so that a smooth increase of the luminance is perceived. Also, in the case in which the LED is shifted from a lit-off state to a light-up state, the same operations can be applied. In this way, the luminance of the first light-emitting diode 7, the second light-emitting diode 11, and the third light-emitting diode 15 can be varied gently with the passage of time t_{11}, t_{12}, t_{13} as shown in Figs. 7a, 7b and 7c, respectively.

Moreover, although, in the above described embodiment, description was made on the case in which the duty cycle of lighting-up and lighting-off the LED varies linearly in every 1/16 section, it will be obvious that the similar effect can

be achieved by changing the duty ratio to be matched with a logarithmic curve or other variation curves in accordance with the variation rate of the luminance which can be visually perceived.

[Advantages of the Invention]

As described so far, according to the present invention, the driving circuit of LED is controlled by switching at a duty corresponding to the elapsed time thereby achieving a significant advantage in that a display device in which shifting from a lit-up state to a lit-off state, or vice versa can be performed with a gradual change of the luminance can be obtained.

[Brief Description of the Drawings]

Fig. 1 is a block diagram to show a conventional control circuit for a light-emitting diode; Fig. 2 is an explanatory drawing to show the luminance change of a LED according to a conventional control circuit for a light-emitting diode; Fig. 3 is a general block diagram to show an embodiment of the control circuit for a light-emitting diode according to the present invention; Fig. 4 is a circuit diagram to show the electric connections of Fig. 3; and Fig. 6 and Fig 7 are diagrams to illustrate the operation thereof.

[Description of Symbols]

7, 11, 15 Light-emitting diode;
21 Control LED determination means;
22 Operating point judgment means;
23 Lighting-up time period determination means;
24 Lighting-up control means;
25 Light-emitting diode;
30 Microcomputer.

Fig. 1

1 Oscillation circuit

2 Counter circuit

3 Decoder circuit

Fig. 2

(a) Lit-up

Lit-off

(b) Lit-up

Lit-off

(c) Lit-up

Lit-off

Fig. 3

21 Control LED determination means

22 Operating point judgment means

23 Lighting-up time period determination means

24 Lighting-up control means

Fig. 4

32 Memory

33 Input circuit

35 Timer circuit

36 Output circuit

Fig. 5

50 Start

51 Select a LED to be controlled

52 Set a minimum lighting-up time ratio t_1 : t_2

53 Light up the selected LED

54 Has time period t_1 elapsed?

55 Light off the selected LED

56 Has time period t_2 elapsed?

57 Repeated specified number of times?

58 Set lighting-up time ratio to a next value as follows:

Fig. 7

(a) Lit-up

Lit-off